

Amendments to the Specification:

Please replace [0001] with the following amended paragraph:

[0001] The present invention generally relates to a grey scale bistable display. More particularly, the invention relates to device configurations and circuitry that may be used to ~~achieve~~ achieve a grey scale bistable display.

Please replace [0037] with the following amended paragraph:

[0037] OLED 170 may further include other layers. Such layer include blocking layers (not shown), adapted to block charge carriers from moving out of emissive layer 134. Such blocking layers are described in more detail in patent application no. 10/173,682 to Forrest (filed June 18, 2002; published December 18, 2003 as U.S. Published Application 2003-0230980A1), ~~Atty.~~ ~~Docket No. 10020-23301~~, which is incorporated by reference in its entirety. Another such layer is a buffer layer disposed beneath second electrode 140, adapted to protect underlying organic layer 130 during the deposition of second electrode 140. An example of a buffer layer material is bathcuproine (BCP). The OLEDs may be comprised of polymeric OLEDs (PLEDs). Examples of PLEDs are disclosed in U.S. Patent No. 5,247,190 to Friend et al., which is incorporated herein by reference in its entirety.

Please replace [0059] with the following amended paragraph:

[0059] In the LOW state, OLED 530 does not emit light, so that the current passing through photodetector 540, I_{PD} , is solely its dark current. By choosing an appropriate resistance "R" for resistor 520, the gate voltage of transistor 510 may be selected such that, in the low state, the gate voltage is between the threshold voltage of transistor 510 and zero ($V_{T1} < V_{g1}^l < 0$, where V_{T1} is the threshold voltage of T1 510, $V_{g1}^l = -|I_{PD}| \cdot R$ 520 is the gate voltage of transistor

transistor 510, and the superscript “*l*” represents the LOW state). Hence, transistor 510 remains off to maintain the LOW state of OLED 530.

Please replace [0060] with the following amended paragraph:

[0060] In the HIGH state, OLED 530 emits light that is directly coupled into photodetector 540 through the transparent cathode of OLED 530, which generates a photocurrent. The properties of photodetector 540 and resistor 520 may be selected such that this photocurrent results in a gate voltage for transistor 510 that is higher than the ~~threshold~~ threshold voltage of that transistor, $V_{g1}^h < V_{T1} < 0$, where the superscript “*h*” represents the HIGH state, such that the HIGH state is maintained. Second transistor T2 550 may be adapted to provide pulses in order to toggle bistable switch 500 between HIGH and LOW states, as shown in Fig. 5. Circuits other than the one specifically illustrated in Figure 5 may be used.

Please replace [0062] with the following amended paragraph:

[0062] Fig. 6 shows a brightness control circuit 600 for an embodiment of the present invention. Circuit 600 includes a first transistor 610 with its drain connected to an OLED 620 and its source connected to a first reference voltage source, V1. OLED 620 is also connected to voltage V2. Circuit 600 also includes a second transistor 630 with its source connected to a voltage source V4, and its drain connected to a photodetector 640. Although not shown in Fig. 6, OLED 620 provides light to photodetector 640 as illustrated, for example, in ~~Figs~~ Figs. 1-4. A pulse may be provided at the gate of ~~transistor~~ transistor 630, and the voltage between V3 and V4 read by external circuits. The voltage difference between V3 and V4 provides a measure of the amount of light being emitted by OLED 620, because photodetector 640 is absorbing some of that light. External circuits may further be used to control the gate voltage of transistor 610 and / or the voltage difference between V1 and V2, to adjust the amount of light being emitted by OLED 620. The brightness of OLED 620 may therefore be maintained at a desired level.

Please replace [0064] with the following amended paragraph:

[0064] Fig. 7 shows a top view of a device 700 fabricated in accordance with an embodiment of the present invention. Device 700 includes a plurality of first electrode strips 710. A second electrode strip 730 is disposed perpendicularly over first electrode strips 710. A third electrode 720 is disposed over second electrode strip 730 at the intersection of first electrode strips 710 and second electrode strip 730. The organic layers of an OLED (not shown) may be disposed between first electrode strips 710 and second electrode strip 730. The photodetector active region (not shown) of a photodetector may be disposed between second electrode strip 730 and third electrode strip 720. Figure 7 illustrates a particular configuration that was used for experiments, and it is understood that many configurations of electrodes, including conventional active matrix and passive matrix configurations, may be used in connection ~~with embodiments~~ with embodiments of the present invention.

Please replace [0068] with the following amended paragraph:

[0068] A pixel having different grey scale levels may be achieved by using a pixel having bistable subpixels with different areas that emit ~~substantially~~ substantially the same spectra of light at substantially the same intensity. Fig. 15 illustrates an embodiment of such a pixel, pixel 1510, which has four subpixels 1520, 1530, 1540 and 1550. Each subpixel has an area that is 50% of the preceding subpixel, i.e., subpixel 1530 has 50% of the area of subpixel 1520, subpixel 1540 has 50% of the area of subpixel 1530, and so on. The subpixels are designed to be driven at the same intensity per unit of surface area, such that the total intensity of light emitted by a subpixel is proportional to its surface area. Thus, the subpixels may be driven by the same drive voltage Vdd carried by the same bus line 1560. The number of grey scale level that may be achieved by the specific approach illustrated in Figure 15 is 2^n , where n is the number of subpixels per pixel. The approach of Figure 15 allows for a greater number of grey scale levels per subpixel than the approach of Figure 14. Using subpixels having different areas, however, may complicate fabrication and reduce fill-factor. Specifically, the inactive border around each subpixel may have a width determined by manufacturing constraints, such that the inactive

region necessitated by small subpixels such as subpixel 1550 is proportionally larger than the comparable inactive region necessitated by a larger subpixel, such as subpixel 1520. Also the requirement of different subpixel sizes may adversely affect the display resolution that may be obtained, as manufacturing considerations may constrain the size of the smallest subpixel, and much larger subpixels must also be fabricated.

Please replace [0069] with the following amended paragraph:

[0069] In a preferred embodiment, a pixel having multiple grey scale levels using bistable subpixels may be achieved by using subpixels having substantially the same area and emitting substantially the same spectra of light in the ON state, but at a different time-averaged intensity. The subpixels may be driven in a different manner while in the ON state such that each subpixel emits a different amount of light over a given time period. Fig. 16 illustrates such an embodiment. Pixel 1610 includes bistable subpixels 1620, 1630, 1640 and 1650. Each subpixel has substantially the same area, and emits substantially the same spectra of light in the ON state. The subpixels may emit different intensities of light.

Please replace [0073] with the following amended paragraph:

[0073] In a preferred embodiment, pulse width modulation of the power signal is used to control the intensity of a subpixel. Specifically, the amount of energy provided to a subpixel is controlled relative to the amount of energy provided to other subpixels by varying the amount of time that power is provided. For example, Vdd1 may provide power all of the time, Vdd2 may provide power 50% of the time, Vdd3 may provide power 25% of the time, and Vdd4 may provide power 12.5% of the time. As a result, Vdd2 provides 50% of the energy provided by Vdd1, and so forth. The frequency of the power signal is preferably sufficiently great that a viewer does not notice that a subpixel is flickering between on and off. Rather, the viewer perceives the subpixel as emitting light of a reduced intensity, depending upon the amount of time that the subpixel is emitting light. This intensity may be referred to as the "time-averaged luminance." In fact, the peak luminance (and the corresponding peak voltage) emitted by each

subpixel is preferably the same, such that the differences in the time-averaged luminance emitted by each subpixel are due solely to the fraction of time that each subpixel is emitting light. It is believed that the perceived intensity of a subpixel is a simple linear function of the amount of time that the subpixel is emitting light. As a result, a subpixel having 50% of the time-averaged luminance of another subpixel may be achieved by providing a power signal that provides power for only 50% of the time. Circuitry that controls the power provided by power lines 1625, 1635, 1645 and 1655, such as circuitry 1660, is well within the skill of one of skill in the art in view of this disclosure. The frequency with which the power in each line is turned on and off may be ~~suffieently~~ sufficiently great that the effect is not visible to the human eye. The circuit used to maintain the bistable subpixels in the ON or OFF states may have a decay constant such that the cycling of the power in each power line does not change the ON or OFF state of a subpixel. As with the embodiment of Fig. 15, 2^n grey scale levels may be achieved, where n is the number of subpixels. Depending upon how pixel intensity varies with with the amount of power provided, the duty cycles may be adjusted such that subpixel 1620 provides full intensity, subpixel 1630 provides 50% intensity (time-averaged luminance), subpixel 1640 provides 25% intensity, and so on. Using subpixels that have substantially the same area may significantly facilitate fabrication and fill factor. However, because some subpixels are not driven at full intensity, the overall brightness of the pixel when all of the subpixels are ON may be less than other embodiments. It is believed that the simplicity of fabrication may outweigh this consideration, particularly for pixels having a small number of subpixels, such as 2-4 subpixels, such that the reduction in overall brightness is not too great.

Please replace [0077] with the following amended paragraph:

[0077] Figure 17 shows an example of a circuit that uses optical feedback to maintain the ON or OFF state of a subpixel, even where power is supplied to the primary light emitting device of a subpixel for a fraction of the time. The circuit has a first OLED 1710, a second OLED 1720, a photodetector 1730, a resistor 1740, a first transistor 1750, and a second transistor 1760. First OLED 1710 is primarily responsible for the light that is transmitted to a viewer, although it is not ~~neecessarily~~ necessarily that all light from OLED 1720 be blocked from reaching the viewer. Preferably, if any light from OLED 1720 reaches a viewer, that light has the same spectra as

light emitted by OLED 1710. Second OLED 1720 is responsible for providing optical feedback to photodetector 1730 when the subpixel is in an ON state. Preferably, OLED 1720 is small relative to OLED 1710, and OLED 1720 is disposed directly over photodetector 1730. The power line that powers second OLED 1720 may be uniform, *i.e.*, always on or “unmodulated,” such that the light emitted by OLED 1720 is not interrupted when the subpixel is in the ON state. Because the primary purpose of OLED 1720 is to provide optical feedback, as opposed to light for the viewer, OLED 1720 may be small relative to OLED 1710. OLED 1710 may be powered by a power line that only provide power for a fraction of the time. Even when OLED 1710 is not receiving power, OLED 1720 continues to provide optical feedback if the subpixel is in the ON state. The state of the subpixel may be changed by applying a signal to the gate of transistor 1750. Other circuits may also be used to provide feedback, whether optical or electrical, to maintain an OLED in an ON state even if the OLED is only powered for a fraction of the time when it is in the ON state.

Please replace [0083] with the following amended paragraph:

[0083] After the ITO sputtering, the sample was transferred into an ultra-high vacuum organic molecular beam deposition chamber with a base pressure of 1×10^{-10} Torr. A layer of MTDATA doped with 2 wt% F₄-TCNQ was deposited onto the OLED cathode. This p-doped layer reduces the dark current of the photodetector while not compromising its quantum efficiency. The 16 alternating layers of the photodetector active region were then deposited by vacuum thermal evaporation, with the first CuPc layer in contact with the MTDATA of the p-doped layer. Then, the second blocking layer was deposited by vacuum thermal evaporation on top of the active region. The sample was transferred to a separate vacuum chamber. The Al cathode was evaporated at 1×10^{-6} Torr through a shadow mask with an opening of $0.8 \times 0.8 \text{ mm}^2$ (720, Fig. 7) aligned to the center of the OLED. The resultant device appeared ~~similar~~ similar to those illustrated in Figure 7, where electrode 730 is $2 \times 2 \text{ mm}$.